

The Fermilab Long Range Plan

Steve Holmes

Accelerator Advisory Committee

May 10, 2004

Fermilab Long Range Planning Committee

Charge from the Director

- Charge: The committee should develop scenarios for each of the two cases spelled out by the HEPAP Subpanel.
 - A linear collider project will be built here, starting late in this decade with international support and organization.
 - The linear collider will be built offshore with substantial participation from U. S. High Energy Physics.
- **FLRPC Membership**

Hugh Montgomery (Chair)	Steve Geer	Gary Feldman, Harvard
Steve Holmes (Deputy)	Chris Hill	Young-Kee Kim, Chicago
Jeff Appel	Bob Kephart	Peter Meyers, Princeton
Joel Butler	Sergei Nagaitsev	Angela Olinto, Chicago
Marcela Carena	Jim Strait	Ritchie Patterson, Cornell
Josh Frieman	John Womersley	

Fermilab Long Range Planning Committee

Chronology

- January-February, 2003
 - Committee appointed, charge drafted and circulated
 - Spring and Summer, 2003
 - Sub-committees formed, work plans established and executed
 - Layout of report established
 - Fall, 2003
 - Open Sessions
 - Drafts of sections of the report discussed in full committee
 - January 9-10, 2004
 - Retreat
 - January- February, 2004
 - Circulate Drafts of sections and complete report
 - February- March 2004, converge, public presentations
http://www.fnal.gov/directorate/Longrange/Long_range_planning.html
 - March- May , complete report (Exec Summary + Rep. ~75 pages)
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Physics Landscape: Revolutions

- The Standard Model is starting to give way to something new.
 - neutrinos have mass and mixing
 - window on a new phenomenon at the Grand Unification Scale?
 - Tevatron(?) and LHC will pull back the curtain on the origin of mass, or electroweak symmetry breaking,
 - SUSY?
 - Extra Dimensions
- New physics questions and exploration of new worlds:
 - New phenomena at the electroweak symmetry breaking scale and beyond;
 - Neutrino masses and mixings; the matter-antimatter asymmetry of our universe;
 - Cosmological and particle astrophysics: dark energy, dark matter.
- New ways of working

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Vision

- The Fermilab Long Range Plan identifies two possible visions for the laboratory in 2015:
 - 1) A linear collider nearing completion in northern Illinois with Fermilab as host laboratory, and Fermilab established as a (the) world center in the physics of the energy frontier for decades.
 - 2) A linear collider elsewhere, or delayed, with Fermilab serving as a world center of excellence in neutrino physics.
- Common elements in either case:
 - LHC participation (detector and accelerator upgrades)
 - Accelerator R&D aimed at the generation beyond either of the above.
- Independent of the two visions, the current plan is the same:
 - Aggressively pursue parallel, success oriented, programs in linear collider and proton driver until the linear collider status clarifies;
 - Pursue R&D aimed at the generation beyond.

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Linear Collider

“We propose to the U.S. and to the international HEP community that we work together to build a linear collider at or near the Fermilab site.” M. Witherell, HEPAP Subpanel, June 12, 2001

- The FLRPC report offers the following recommendations with regard to a Linear Collider:
 - Fermilab reiterate its desire to serve as the host laboratory for a linear collider.
 - A full-time person be appointed within the Directorate with responsibility for coordinating and directing all Fermilab LC activities...
 - Fermilab initiate efforts to establish performance goals and develop design studies for the major test facility (ETF)...required to support either a warm or cold R&D program. This should be done in collaboration with international partners, with a subsequent goal of hosting the major technology demonstration project for the chosen technology.
 - Fermilab planning for a future including the Linear Collider should be based upon the host laboratory/international project model.

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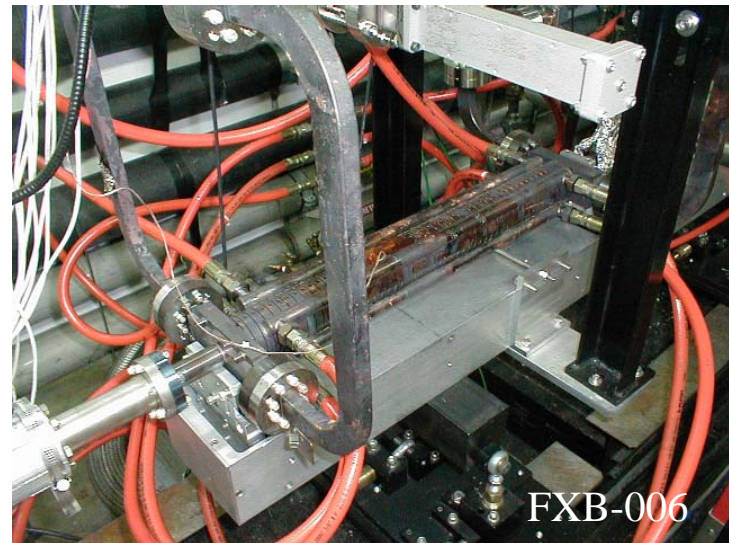
Linear Collider Activities

- Fermilab has been a TESLA collaboration member since the early-1990s.
 - Significant material contributions to the TESLA Test Facility (TTF)
 - Modest continuing consultation support for TTF
 - Damping ring design studies starting up (with U.S. collaborators)
- Fermilab has been a NLC Collaboration member since the mid-1990s
 - Fabrication of accelerating structures
 - For the NLCTA “8-pack” test, and as a basis for industrialization
 - Development of girder designs
 - Coordination of siting studies (IL and CA)
 - Permanent magnets
 - Development of Engineering Test Facility (ETF) design goals/concepts.

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Linear Collider: Fermilab Structures Program

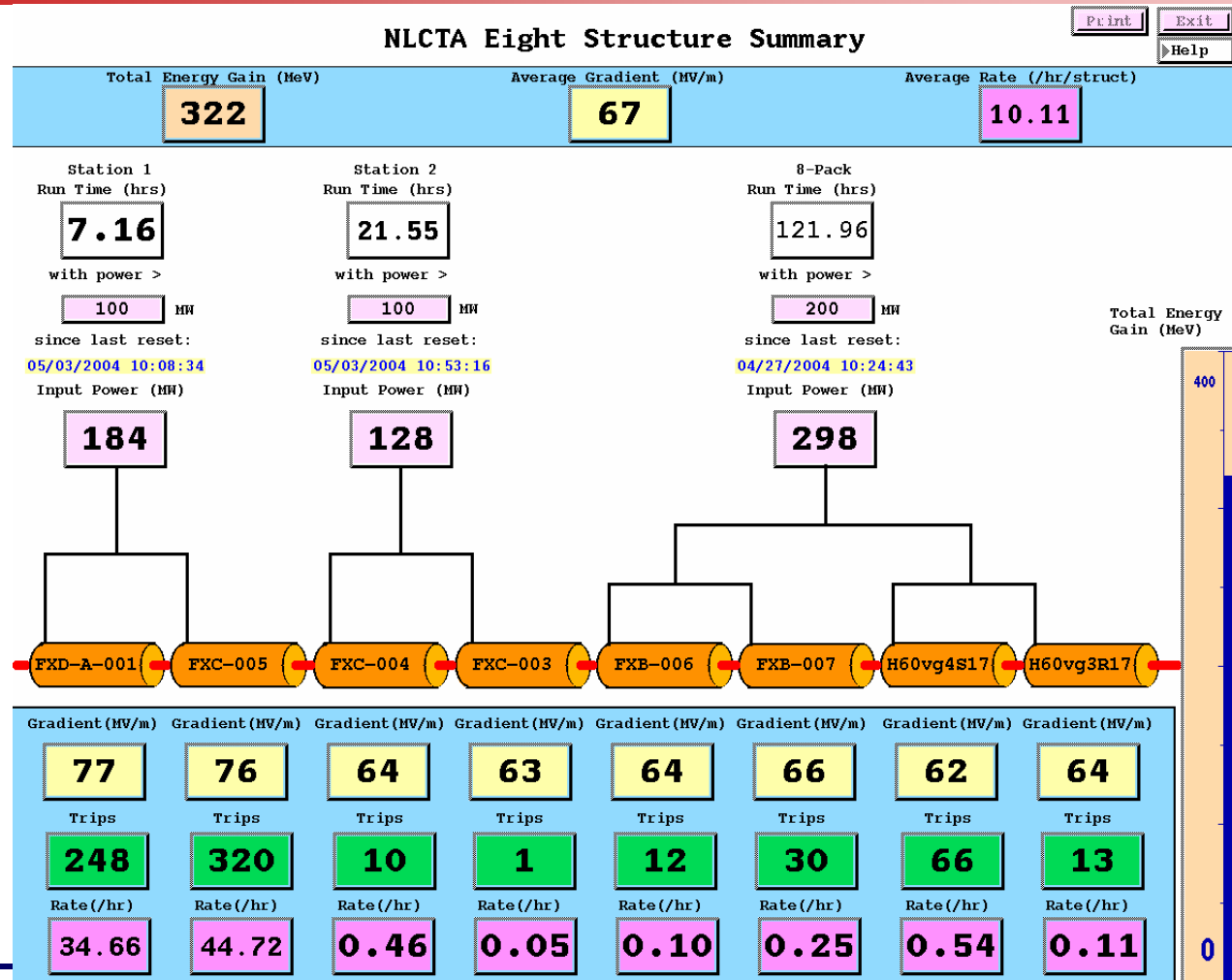
- In 2.5 years Fermilab has gone from no experience in fabrication of electron accelerator structures, to producing the best performing structures in the NLC program
 - Six of eight structures currently operating at NLCTA were fabricated by Fermilab.
 - FXB-006 is the **first structure** built by anyone **to achieve NLC specification for gradient and breakdown rate** (<0.1 breakdown/hour @ 60 Hz, 400 nsec, 65MV/m)
 - FXC series are “full feature”, including damping manifold, structures
 - ⇒ **FXC003 has also met the NLC gradient/breakdown rate criteria**
 - FXDs in processing



Beyond 2010

Fermilab Structures: NLCTA Current (5/3) Status

<http://www-project.slac.stanford.edu/lc/local/projects/nlcta/nlctasumm.html>



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Linear Collider: Fermilab as Host

- The FLRPC advocates preparation of a Fermilab bid to host an international linear collider project and identifies attributes that we believe make Fermilab/northern Illinois very attractive as potential host:
 - Fermilab
 - Scientific and engineering expertise in forefront accelerator technologies
 - Significant experience in construction and operations of large accelerator projects
 - The leadership mantle of U.S. high energy physics
 - Northern Illinois
 - Strong scientific base, including two national laboratories and five major research universities
 - Geology ideally suited to a linear collider
 - Transportation and utilities infrastructure system that could support LC construction and operations.

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Linear Collider: Fermilab as Host

- All discussions of Fermilab as host are in context of a model in which the international linear collider is organized as an international project with a nearby host laboratory, separately managed and each with its own organization.
- Local Siting Studies
 - Four representative Illinois sites have been investigated
 - Three deep, one shallow; two traversing site, two to the west
 - Latest site was investigated as part of the USLCSG study
 - Deep; west; warm and cold incarnations.
 - Collaboration formed with NIU Geology Department in late FY2003

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Linear Collider: Resources

- Total Fermilab effort is ~\$3M; static at this level since FY2001.
 - Represents roughly 15-20% of U.S. effort.
 - Does not include ~\$2M of SCRF R&D, of which 30-50% is LC related.
 - Expect consolidation of NLC and SCRF efforts following technology recommendation.
- The Fermilab investment needs to grow to ~\$20M/year at the time of ETF construction, and to ~\$100M/year at the time of the LC construction start (~1/3 of the laboratory effort) in the Fermilab as host lab scenario
 - Growth of the Fermilab investment during construction and operations will depend strongly on the international governance model agreed to.
 - Could become ~50%
 - ~2/3 of this if LC is in U.S. but not Fermilab
 - ~1/3 of this if LC is off-shore.
 - Accelerator/detector split should be heavily weighted towards accelerator

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Linear Collider

- Fermilab should act swiftly to develop its capability to provide technical leadership on the LC construction.
 - Engagement in critical accelerator technology issues and demonstration project(s).
 - Suggest identifying a limited number (two) of areas in which to concentrate accelerator physics effort with goal of establishing leadership, e.g. main linac, damping rings, and/or sources
 - Siting the Engineering Test Facility at Fermilab would provide a unique opportunity to develop LC expertise within the Fermilab scientific and engineering staffs
 - Target detector R&D in a limited number of areas deemed critical to detector performance in which the lab has special capabilities, for example
 - Computing/simulations, vertexing & tracking, calorimetry, muons
 - Test beams

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Linear Collider

- Fermilab plan for linear collider, including preparation of a bid to host, must be based on visible leadership and enhanced efforts in:
 - Technology R&D
 - Site studies
 - Public outreach
 - Governance models

The plan itself needs to incorporate

- Establishment of a realistic timeline in consultation with national and international partners
- Preparation of the Fermilab component of the U.S. bid to host an international linear collider facility.
- Plans for Fermilab participation in the linear collider in the event that the LC is sited elsewhere.

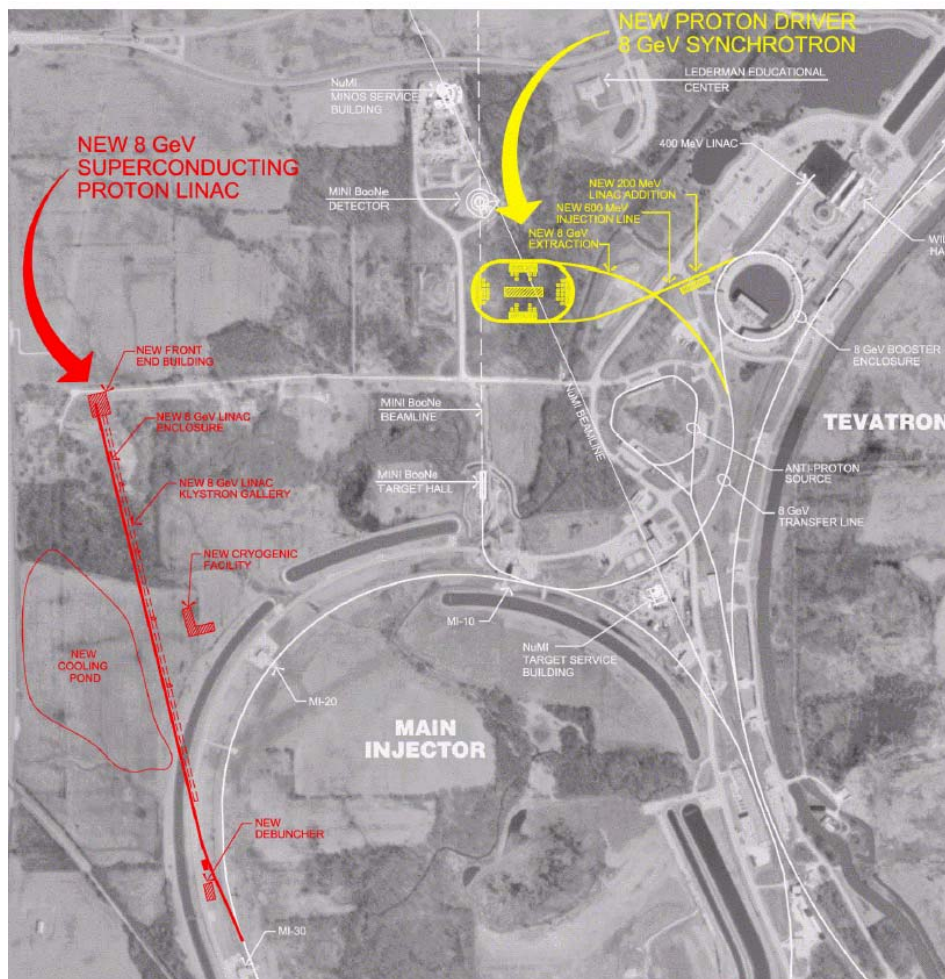
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Proton Driver

- FLRPC Conclusions and Recommendation relative to Proton Driver
 - Understanding the physics of neutrino oscillations, the mass hierarchy, and perhaps CP violation in the neutrino sector requires a new generation of long baseline neutrino experiments, supported by a new, very intense, proton source (aka Proton Driver)
 - We recommend that Fermilab prepare a case sufficient to achieve a statement of mission need (CD-0) for a 2 MW proton source (Proton Driver). We envision this project to be a coordinated combination of upgrades to existing machines and new construction.
- High level parameters:
 - 0.4 MW of beam power at 8 GeV ($20 \times$ current Booster)
 - 2.0 MW of beam power at 120 GeV ($6 \times$ current Main Injector)

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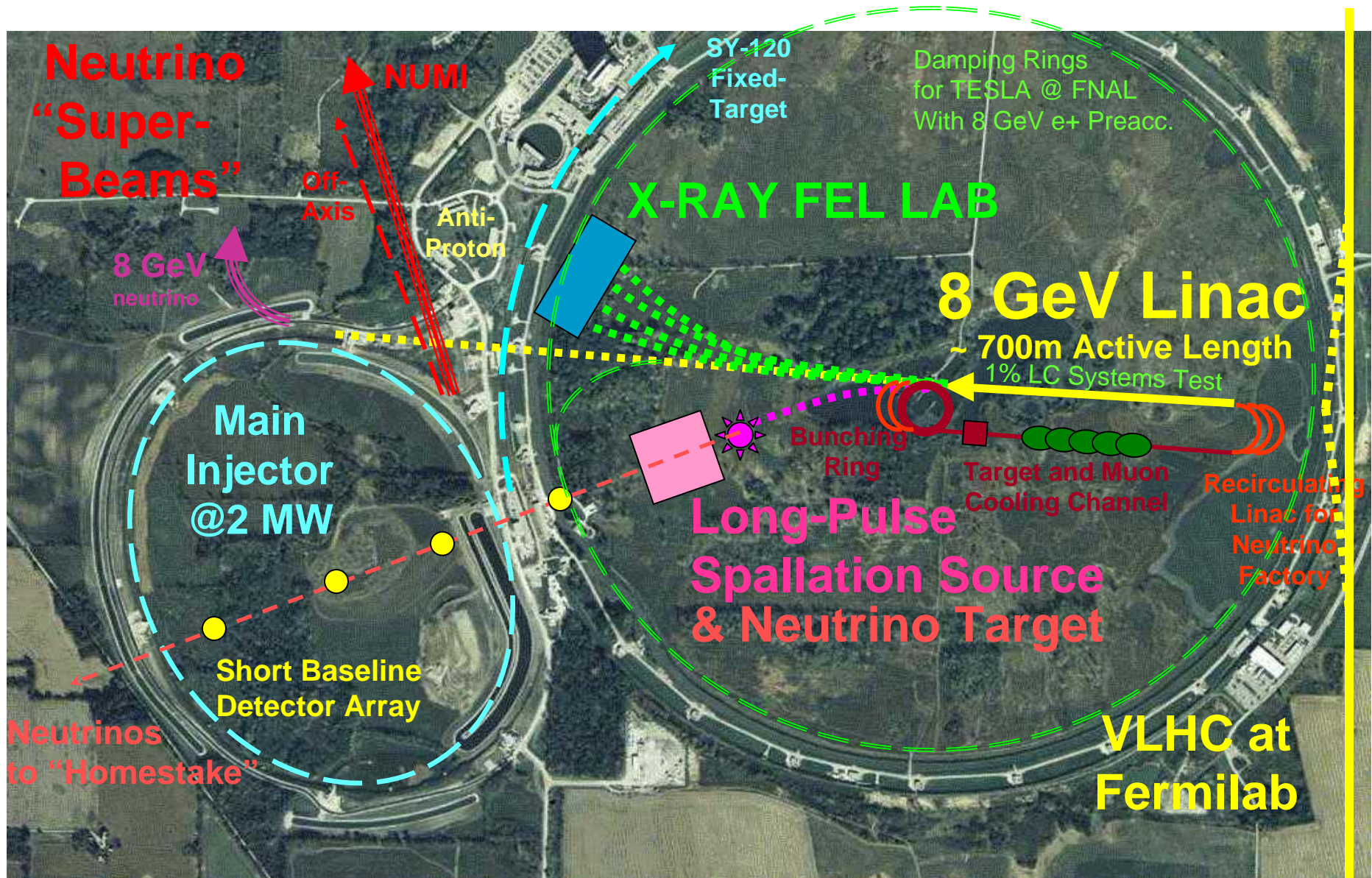
Proton Driver



- Possible Proton Driver implementations:
 - 8 GeV synchrotron; or
 - 8 GeV superconducting linac
- Both inject directly into the Main Injector, enabling forefront program at 8 GeV, 120 GeV, or anywhere in between.
- The SC linac is preferred:
 - Better performance over entire energy range.
 - Flexibility for the future.
 - But undoubtedly costs more

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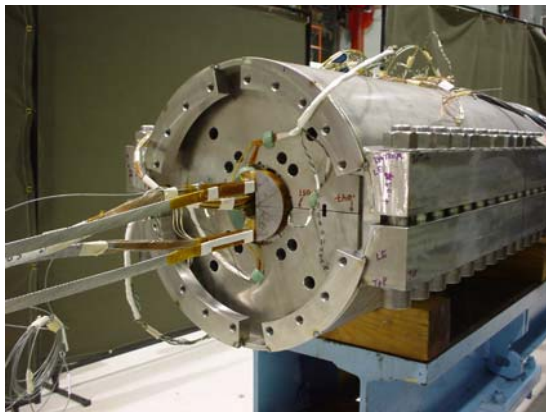
Proton Driver: Multiple Missions



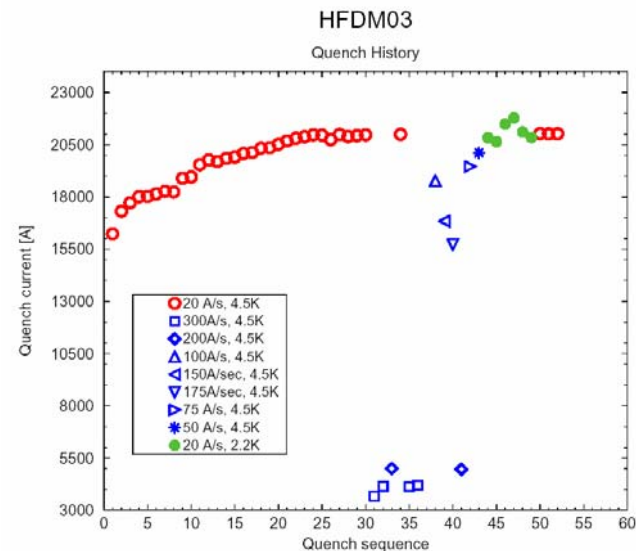
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LHC Upgrades

- The LHC Accelerator Research Program is being established as a continuation of the U.S. LHC Accelerator Project.
- The Fermilab proposed responsibility is the development of next generation IR quadrupoles based on Nb₃Sn technology.
- Natural outgrowth of our high field magnet R&D program:



HFDM03: First Fermilab Nb₃Sn dipole to reach short sample.



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Getting There

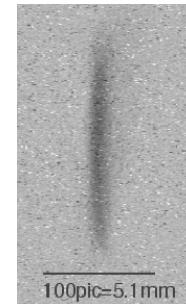
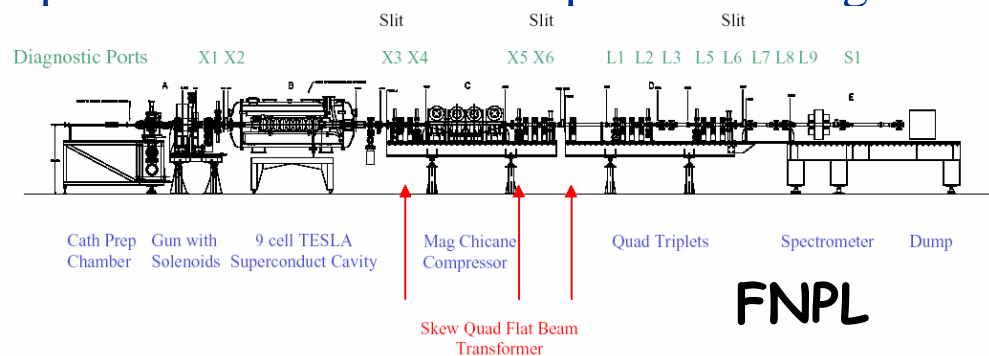
- To implement the recommendations of the FLRPC the Director has issued charges to the LC and PD groups.
 - LC aims at implementing recommendations of the FLRPC in the areas of establishing leadership roles and implementing outreach.
 - Foresees consolidation of resources following technology decision.
 - PD aims at developing the physics case, and developing the SC linac technology to the point that a cost benefit analysis can be done, and the linac/synchrotron technology selection made.
 - The Linear Collider/Proton Driver decision can only be made in consideration of:
 - A better understanding of prospects for the LC (where, when, if, how)
 - The development of understanding of basic neutrino parameters (e.g. $\sin^2 2\theta_{13}$) and capabilities of other facilities (e.g. J-PARC)
 - Funding roll-off of BTev.

⇒ **Guess ~2008 for decision**
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Accelerators for the Far Term

- We need to be looking one generation beyond what is described above:
 - Neutrino Factory: ionization cooling, rf acceleration, sc magnets; MTA
 - Hadron Colliders beyond LHC: sc magnets, high brightness protons
 - New methods of acceleration: Plasmas, lasers, etc; Fermilab-NICADD Photoinjector Laboratory
- Fermilab provides leadership, based on modest efforts, in all these activities, and believes this is an essential part of our mission.
- There are multiple synergies here, and opportunities for collaboration, in particular centered on superconducting rf.



Summary

- The Fermilab Long Range Plan establishes two visions for what Fermilab can look like in the middle of the next decade
 - LC host
 - Neutrion Central
- The strategy at the moment is establishment of parallel, success oriented, programs in each
 - Charge letters issued
 - Resources being allocated
- Decision point in ~2008